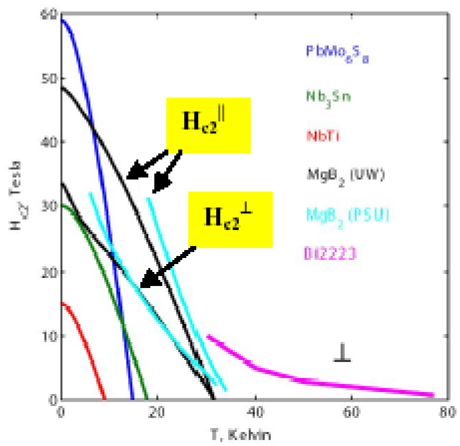
IRG2 Nugget 1: **High-field Superconductivity in Magnesium Diboride Alloys.**



Practical performance of superconductors is limited by their upper critical magnetic field Hc2(T) at which bulk superconductivity is destroyed. Recent extensive studies of the scattering effects of impurities and disorder in MgB2 performed by IRG2 in collaboration with other experimental groups have shown that Hc2(T) can be increased by more than ten times beyond that of pure samples and single crystals [1,2]. In particular, in collaboration with Penn State University, we have shown that Hc2(0) of some carbon-doped MgB2 films can even approach the paramagnetic limit. The figure compares the Hc2(T) envelope of "alloyed" MgB2 to that of two Nb-based superconductors, from which modern superconducting magnets are made, and PbMo6S8, the best of the low temperature superconductors, from which useful wires have never been made. The magnetic irreversibility field at which the critical current vanishes, is also shown for the high-temperature superconductor (Bi,Pb)2Sr2Ca2Cu3O10-x. The upper critical field of MgB2 exceeds Hc2(T) of Nb3Sn at all temperatures and can handle at 20 K (a temperature accessible to efficient cryocoolers), the same magnetic field that the workhorse material NbTi can only handle at 4 K, the temperature of boiling liquid helium. Moreover, unlike high temperature superconductors such as (Bi,Pb)2Sr2Ca2Cu3O10-x and YBa2Cu3O7-ä, which require strong crystallographic texture to ameliorate current blockage at high-angle grain boundaries, grain boundaries in MgB2 are transparent to current flow. Thus, round wire, rather than tape conductors are feasible from MgB2. The strong enhancements of Hc2(T) found in IRG2's work are a direct consequence of the two-gap physics of this novel material, which allows significant increase of Hc2 by optimizing the intraband scattering rates via selective atomic substitution on Mg and B sites [3].

References:

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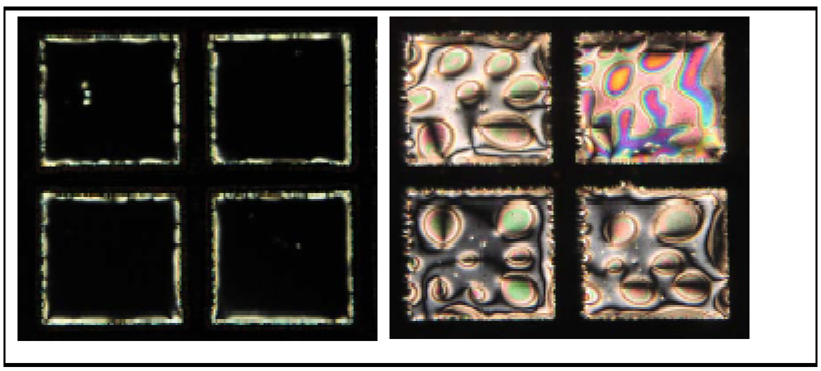
2. V. Braccini, A. Gurevich, J.E. Giencke, M.C. Jewell, C.B. Eom, D.C. Larbalestier, A. Pogrebnyakov, Y. Cui, B.T. Liu, Y. F.Hu, J. M. Redwing, Qi Li, X.X. Xi, R.K. Singh, R. Gandikota, J. Kim, B. Wilkens, N. Newman, J. Rowell, B. Moeckly, V. Ferrando, C. Tarantini, D. Marré, M. Putti, C. Ferdeghini, R. Vaglio, E. Haanappel "High-field superconductivity in alloyed MgB2 thin films" (submitted to Phys. Rev. Lett. 2004).

3. A. Gurevich “Enhancement of the upper critical field by nonmagnetic impurities in dirty twogap superconductors”, Phys. Rev. B **67**, 185415 (2003).

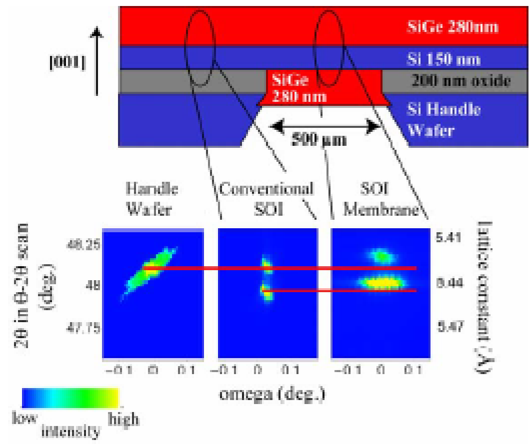
***IRG3 Nugget 1:* Rapid Real Time Detection of Proteins Binding to Receptors Using Liquid Crystals**

The development of general and facile methods to report the presence of biological molecules will enable a myriad of new technologies, including technologies capable of detecting biowarfare agents or providing fundamental insights into what makes a cell "tick". As reported in the December 19 edition of Science, researcher at the Materials Research Science and Engineering Center at the University of Wisconsin have discovered that it is possible to combine the liquid crystals found in lap-top computer displays with components of biological membranes (lipids) to provide a means to achieve real time imaging of binding events of proteins to receptors. The lipids are assembled on the surface of the liquid crystals, and when proteins bind to them, the liquid crystals change their optical appearance in much the same the same way that an image is created on a laptop computer. The change in appearance of the liquid crystal is striking to the eye (see image), and suggests ways of creating biosensors that do not require complex instrumentation.



Caption: Optical appearance of liquid crystal before (left) and after (right) addition of a protein (phospholipase A2) to an aqueous solution contacting a liquid crystal hosted in a grid containing four quadrants. Each image is approximately 0.5mm across.

***IRG 1 Nugget:* Strain Sharing in Epitaxial Nanostructures**



It is often desirable to integrate materials of differing compositions using heteroepitaxial growth, the continuation of a single crystal through the interface between distinct materials. The most general rule of materials integration using this approach has been that the growth of thin films depends on the degree of lattice mismatch between the materials. Conventionally, thin films without defects can only be grown when the lattice constants of the film and substrate are equal. Often it is highly desirable, but technically difficult to integrate materials of different lattice constants, or to introduce strain into otherwise structurally perfect thin films. When thin films are grown on crystals much thinner than the critical thickness for the formation of defects in the films, however, these mechanical constraints are dramatically different. The mechanical strain due to the mismatch of lattice constants can be shared between the film and the template crystal.

We have found that silicon germanium alloys grown on thin membranes machined from silicon-on-insulator substrates elastically distort the membrane and partially relax towards their equilibrium lattice constant – without the formation of structural defects. This effect can be observed in synchrotron x-ray diffraction measurements, shown in the figure, which compare the membranes to adjacent mechanically constrained areas. Our new ability to manipulate strain in nanometer scale structures will be useful in developing new strategies in the formation of high electron mobility strained silicon layers and in the integration of a wide range of materials.

IEG Education Nugget 1: **UW-MRSEC Outreach Impacts the Public through the Engineering EXPO and Nano EXPO**

MRSEC Engineering Expo April 10-12, 2003

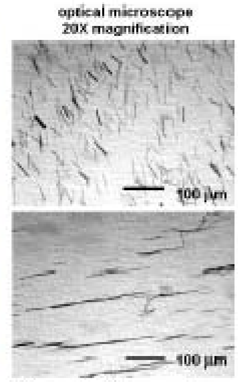
EXPLORING THE NANOWORLD

Nano All Around Us
May 30-31, 2003
University of Wisconsin-Madison
http://nano.engr.wisc.edu

The University of Wisconsin-Madison MRSEC provided educational materials and outreach personnel in two large-scale science and technology expositions.

The biannual, three-day Engineering Expo, hosted by the University of Wisconsin – Madison College of Engineering, is designed to showcase the world of engineering and science to young students and the public. UW MRSEC graduate students, post docs, and faculty led table-top demonstrations, and the UW MRSEC Interdisciplinary Education Group showcased its interactive nanotechnology demonstration in a public presentation entitled "Materials Science: Creating the Building Blocks of Engineering." The UW MRSEC demonstration room was one of the best attended features of the EXPO and required over 70 volunteers for the 3-day event. More details of the presentations and the activity guides associated with the various topics covered can be found at: http://mrsec.wisc.edu/edetc/Expo03/index.html

IEG Education Nugget 2: New Laboratory on Synthesis and Magnetic Manipulation of Nickel Nanowires Is Added to the _Laboratory Manual for Nanoscale Science and Technology_



Several new experiments have been added to the video-based *Laboratory Manual for Nanoscale Science and Technology,* including a lab developed by Anne Bentley, an NSF Graduate Fellow, and personnel from the University of Wisconsin-Madison MRSEC Interdisciplinary Education Group. In this experiment, students prepare and analyze nickel nanowires using a template synthesis technique commonly found in the scientific literature. Electrodeposition of nickel to fill the nanopores pores of a commercially available alumina filtration membrane is accomplished using a nickel salt solution and a AA battery. The nanowires (which are 200 nm in diameter and up to 50 µm long) can be liberated from the membrane by dissolving both the silver cathode and the alumina template. Suspensions of nanowires can be dispersed on a microscope slide and observed using an optical microscope with a 10X or 50X lens. The alignment and movement of the magnetic nanowires can be controlled using common magnets. This experiment is appropriate in the general chemistry curriculum and gives students a hands-on experience in nanotechnology.

High school and college students can learn about nanotechnology and how nanoscale materials are made using this experiment, which requires only a modest investment in time and budget. The nanowire synthesis lab uses a simple electrochemical method to make nickel nanowires and common optical microscopy to analyze their behavior in a magnetic field. Field-testing of this lab has occurred in a variety of courses ranging from introductory chemistry and materials science courses to a graduate level physics course and several institutions including Beloit College, Milwaukee School of Engineering, and the University of Wisconsin – Madison. Most students reported they had never heard of nanotechnology before the lab, and they liked the fact that it was relevant to current research and emerging technologies. The vast majority of student teams were able to successfully create and manipulate nanowires.